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Research Article

OILCROP-SUN Model as a Grower's Tool for Sunflower Cultivation in Irrigated Plains of Punjab

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ABSTRACT

Crop simulation model can serve as an agronomic tool to study uncertainties in crop production due to weather variability. The OILCROP-SUN simulated crop phenology, growth and yield attribute for sunflower cultivars and were in close agreement with field observations under different environments. In case of cv. PSFH-118, the flowering was estimated within -10 to +2 days and physiological maturity within -9 to +7 days of those observed in the field. In case of cv. SH-3322, the flowering date was within -11 to +8 days and physiological maturity was within -7 to +7 days of those observed in the field. The model overestimated the growth (maximum leaf area index, LAI) and yield attributes (grain and biomass yields) for both the cultivars under different environments. The OILCROP-SUN model was employed to simulate the influence of date of sowing of sunflower crop from December to third week of March. The simulation results indicates that if sunflower is planted in December after the harvesting of cotton and early potato crop, the optimum time for sowing falls in within 3rd week of December. However for the spring season, the optimum sowing period comes during 2nd fortnight of February. Further the potential yield of sunflower could be attained with row-to-row spacing of 45 cm and plant-to-plant spacing of 30 cm, *i.e.*, 7.4 plants m^{-2} could be the most appropriate plant population. The OILCROP-SUN model can be used as a user friendly grower's tool in Punjab, India.

Key words: OILCROP-SUN model, Sunflower, Grower's tool

Introduction

Sunflower is one of the most important annual crop in the world for edible oil. As on 2011-12, the crop is cultivated in India on 0.72 Mha with an average productivity of 692 kg ha^{-1} and total production of 0.50 Mt (Anonymous, 2013). It is cultivated by the Punjab farmers on a large scale because of wide adaptability to different crop seasons and soil types, hardiness to drought conditions, high economic returns per unit area, and ability to fix in different cropping patterns.

The yield of sunflower is highly dependent on environmental and crop management factors. Field experiments to evaluate agronomic practices are laborious, time consuming and expensive; especially when a number of variables are to be tested, and require multi-year data for verification. Use of crop simulation model provides a suitable tool to evaluate crop growth as affected by various management and environmental factors and their interactions. A robust simulation model can help to evaluate treatment response on crop growth and yields (Jones *et al.*, 2003).

OILCROP-SUN is a process based model of sunflower crop (Villalobos *et al.*, 1996). It

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simulates organ biomass, N content, LAI and soil water and N balance with daily time step. The model is compatible with DSSAT (IBSNAT, 1989), which permits management strategy evaluation analyses to be performed using the model in combination with multiyear weather records. The standardized input formats for soil and weather data used by the model are those specified for DSSAT (Hoogenboom *et al.*, 1999).

In the present study, an attempt was made to calibrate and validate the OILCROP-SUN model for commonly sown cultivars of sunflower and then illustrate the application of the model as a user friendly grower's tool to evaluate the various agronomic practices for optimum crop production in the state of Punjab, India.

Materials and Methods

Site description

The soil, crop and weather data used in the study were collected from the research farm at Punjab Agricultural University, Ludhiana (30^0 54' N latitude; 75^0 48' E longitude; elevation 247m above mean sea level) (Fig. 1). The study area is characterized by subtropical, semiarid climate.

Data description

Field experiments were conducted during *rabi* 2003-04, 2004-05 and 2005-06 at the research farm of Punjab Agricultural University, Ludhiana.

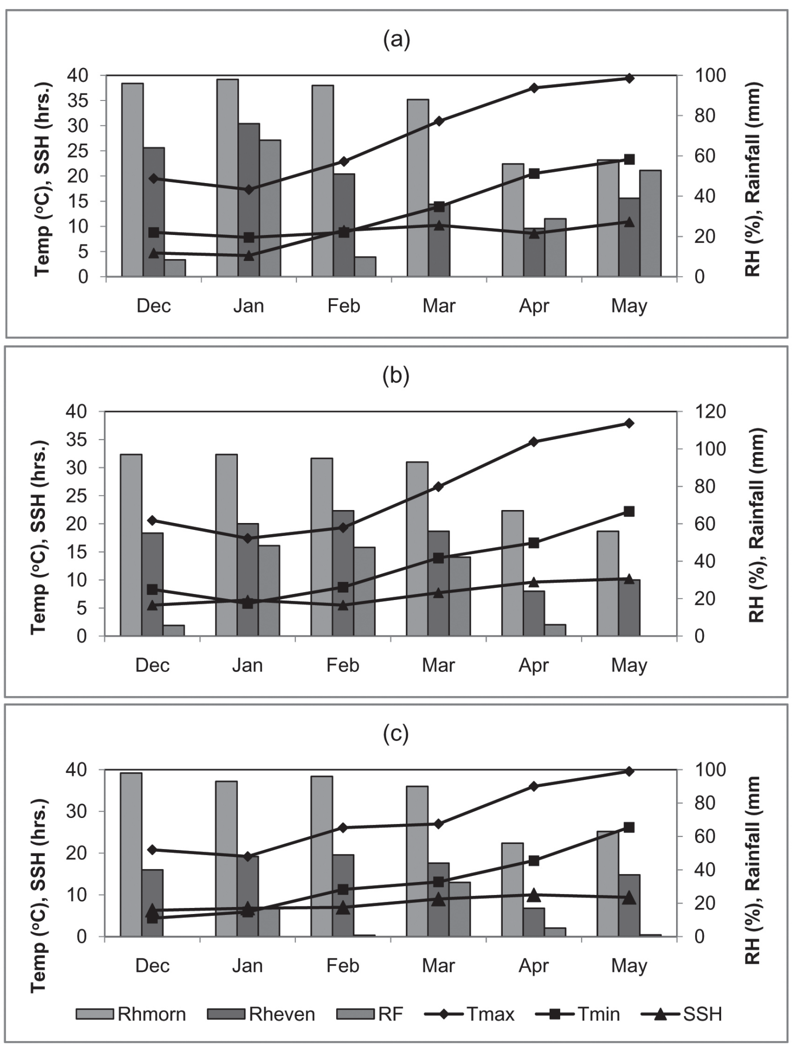

Fig. 1. Monthly meteorological parameters during the crop seasons (a) 2003-04, (b) 2004-05, (c) 2005-06

Two sunflower cultivars (PSFH-118 and SH-3322) were sown under three dates (2nd week of December, January and February) and three irrigation regimes (I_1: 7 DAS + 8 leaf stage + star stage + bud formation + start of flowering+ 50% flowering + complete flowering + grain filling; I_2: 7 DAS + star stage + 50% flowering+ grain filling; and I_3: 7 DAS + 8 leaf stage + grain filling). The crop was raised with row-to-row and plant-to-plant spacings of 60 and 30 cm with a seed rate of 2 kg ha^{-1}. Recommended fertilizers were applied as N @125 kg ha^{-1} (½ at sowing and ½ at 30 days after sowing) and single superphosphate @187.5 kg ha^{-1}.

The phenological events starting from emergence to physiological maturity were identified by observing the plants at 1m row length of each plot. Plant samples were collected at 15-dys interval, and leaf area and dry matter were recorded. The weather data were collected from the meteorological observatory of the Punjab Agricultural University, Ludhiana. Recommended crop management practices were assumed in using the model in order to evaluate various ranges of agronomic practices. In this study, systematic simulations were done by changing one of the variables, while keeping the other variables constant.

OILCROP-SUN model

The OILCROP-SUN model is a physiology based dynamic simulation model and is sensitive to cultivar choice, planting date, row and plant spacing, irrigation management and nitrogen management options. The standardized input formats for soil and weather data used by the model are those specified for DSSAT V3.5 (Hoogenboom *et al.*, 1999). Input requirements for DSSAT include weather and soil conditions, plant characteristics, and crop management.

The minimum weather input requirements of the model are daily solar radiation (MJ m^{-2} d^{-1}), maximum and minimum temperatures (°C) and precipitation (mm). Soil inputs include albedo, evaporation limit, mineralization factor, pH, drainage and runoff coefficients. The model also requires water holding characteristics, saturated hydraulic conductivity, bulk density and organic carbon for each individual soil layer.

The sensitivity analysis was performed for 6 cultivar specific constants (P1, P2, P5, G2, G3 and 01) which control the phenological development, growth and yield of the sunflower crop (Table 1). The grain yield of the sunflower was found to be sensitive at three phenological constants. When the values of P1, P2 and P5 were increased, it resulted in change of the phenological development of the crop, *i.e.*, the duration of vegetative and reproductive stage was affected and as a result, the grain yield was changed. However, the grain yield was not much sensitive to change in the growth coefficients G2, G3 and 01.

The model was calibrated for sunflower cv. PSFH-118 and SH-3322 for first date of sowing. The simulated and field observed values of flowering and physiological maturity date, maximum LAI, grain weights and yield, biomass and stalk yields were compared. The genetic coefficients with least differences between observed and simulated values were selected. The calibrated values used in the study were P1- 240, P2 - 1.20, P5 - 745, G2 - 2900, G3 - 2 and 01 - 65 (for cv. PSFH-118) and P1- 240, P2 - 1.3, P5 - 750, G2 - 2900, G3 - 2 and 01 - 65 (for cv. SH-3322).

Management input information included plant population, planting depth, and date of planting. The latitude was required for calculating day length.

Results and Discussion

Validation of OILCROP-SUN model

The model was validated for phenology, growth and yield of sunflower cultivars *viz.*, PSFH-118 and SH-3322 for different environments during the three crop seasons.

Crop phenology

The major phenological events like flowering and physiological maturity dates were simulated by OILCROP-SUN model and those actually observed in the field for sunflower cultivars under

Table 1. Sensitivity test results for genetic coefficients of OILCROP-SUN model

S. No.	Genetic coefficients	Range	Grain yield (kg ha^{-1})
Phenological coefficients			
1.	P1 : Duration of juvenile phase (in ^{o}C-d with a base temperature of 4 ^{o}C)	220.0	3571
		200.0*	2487
		180.0	2217
2.	P2 : Amount (in day or hour) that development is slowed when crop is grown in photoperiod shorter than optimum (15 h)	0.20	2488
		0.15*	2487
		0.10	2486
3.	P5 : Duration of the first anthesis-physiological maturity stage (in ^{o}C-d with a base temperature of 4 ^{o}C)	900.0	2711
		700.0*	2487
		500.0	2352
Growth coefficients			
4.	G2 : Maximum possible number of grains per head (measured in plants grown under optimum conditions and low plant population density)	3000	2487
		2900*	2487
		2800	2487
5.	G3 : Potential kernel growth rate during the linear kernel filling phase (in mg/day, measured in plants grown under optimum conditions and low plant population density)	3.00	2487
		2.90*	2487
		2.80	2488

* Original constant values

different environments, and are given in Fig. 2 & 3, respectively. The model either overestimated or underestimated these events. In case of cv. PSFH-118, the flowering date was estimated within -10 to +2 days and physiological maturity date within -9 to +7 days of those actually observed in the field. In case of cv. SH-3322, the flowering and physiological maturity dates were

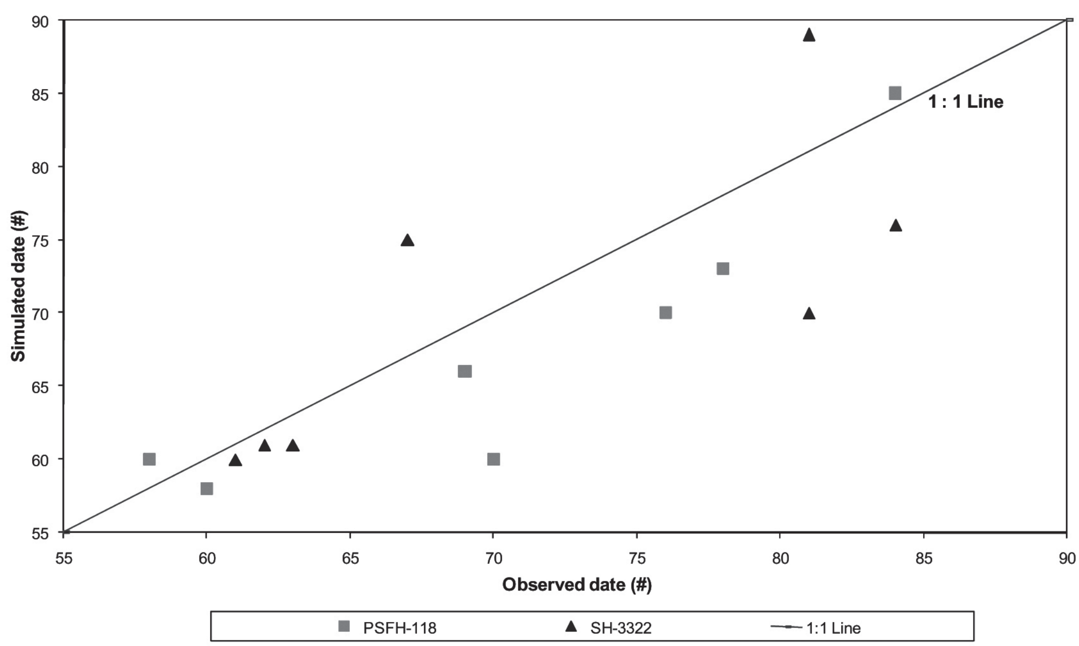

Fig. 2. Comparison between observed and simulated flowering dates in sunflower cultivars under different environments (2003-04, 2004-05 and 2005-06)

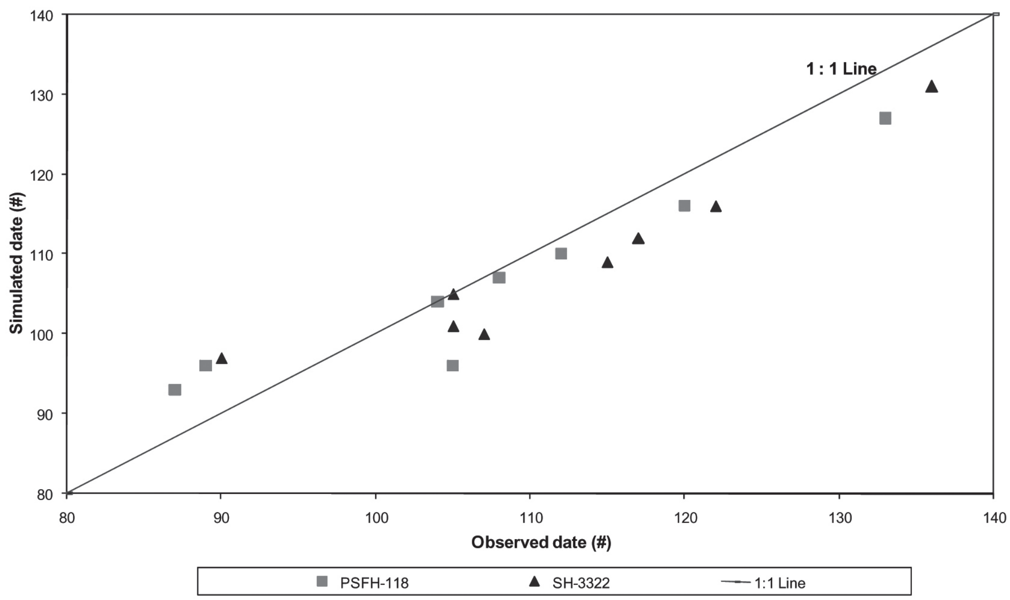

Fig. 3. Comparison between observed and simulated physiological maturity dates in sunflower cultivars under different environments (2003-04, 2004-05 and 2005-06)

estimated within -11 to +8 and -7 to +7 days of those actually observed in the field.

Crop growth and yield

The model simulated maximum LAI, grain yield, grain weight, number of grains head^{-1}, stalk yield and biomass yield for sunflower cultivars. The simulated values were in close agreement with field observations under different environments. The comparison of model simulated and actual maximum LAI, number of grains head^{-1}, grain and biomass yields under different environments are shown in Figs. 4, 5, 6 and 7, respectively.

Out of 24, maximum LAI was underestimated in 8 and overestimated in 16 environments for cv. PSFH-118; and underestimated in 9 and overestimated in 15 environments for cv. SH-3322. In cv. PSFH-118, maximum LAI were underestimated to 20% in 4 and > 20% in 4 environments; and were overestimated up to 20 % in 6 and > 20% in 10 environments. In case of cv. SH-3322, maximum LAI was underestimated in 4 (up to 20%) and in 5 (>20%) environments; and overestimated to 20% (5 environments) and >20% (10 environments). Overall, model simulations indicated a fairly good degree of agreement as well as the dynamic nature of the model (Wajid, 2010).

Similarly, number of grains head^{-1} were underestimated in 9 environments (6 with up to 15% underestimation and 3 with >15% underestimation). Out of 15 overestimated environments the number of grains head^{-1} were overestimated up to 15% for cv. PSFH-118 and SH-3322 in 10 and 9 environments, respectively.

The model overestimated the grain and biomass yields for both the cultivars under different environments. Grain yields were overestimated up to 40 % in 11 and 15 treatments in cv. PSFH-118 and cv. SH-3322, respectively; while the biomass yield were overestimated up to 40% in 9 and 12 treatments, respectively. Similar results were reported by Wajid (2010).

Application of OILCROP-SUN as a grower's tool

The OILCROP-SUN model can be used to simulate the effect of planting date, row-row spacing, plant population, planting depth, amount and time of irrigation and fertilizer application on growth and yield of sunflower crop. The results of some sample case studies using the genetic

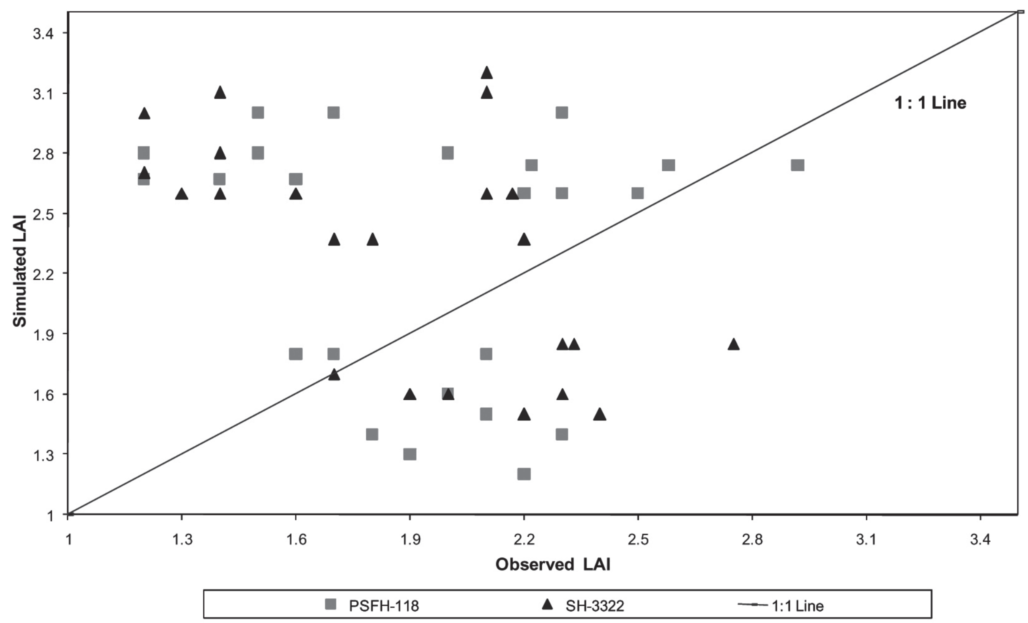

Fig. 4. Comparison between observed and simulated maximum leaf area index in sunflower cultivars under different environments (2003-04, 2004-05 and 2005-06)

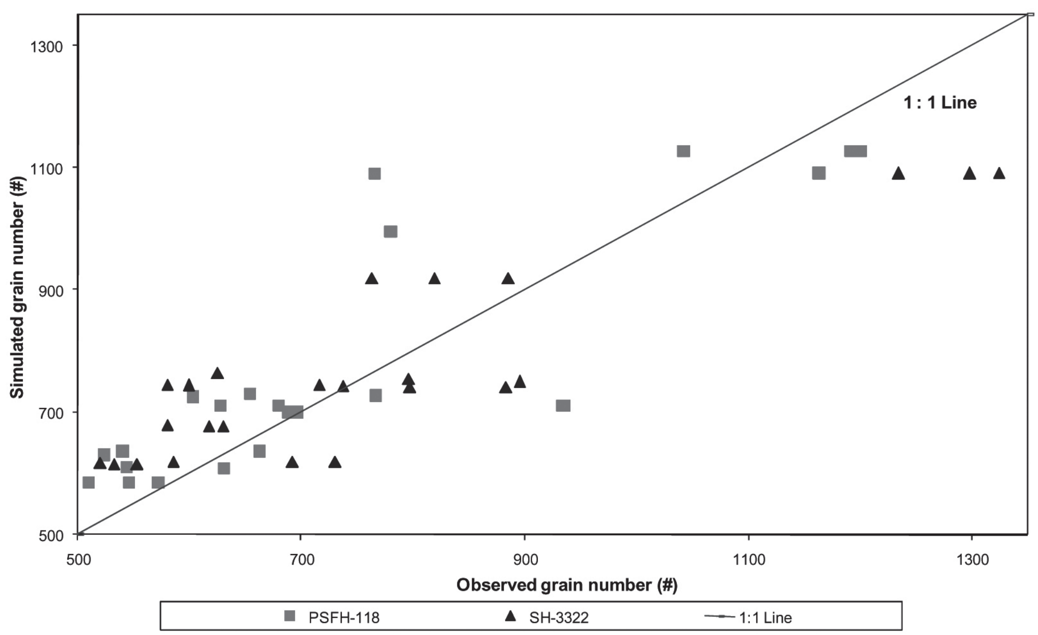

Fig. 5. Comparison between observed and simulated number of grains head^{-1} in sunflower cultivars under different environments (2003-04, 2004-05 and 2005-06)

coefficients of Sunflower cv. PSFH-118 are presented in Table 2 and 3.

For cool season crops like sunflower, the time of sowing is extremely important. The simulation results indicated that if the crop is planted in December after the harvesting of cotton and early potato crop, then the optimum sowing time should be 3rd week of December (Table 2). However for spring season sowing, the optimum sowing period should be the second fortnight of February.

Crop geometry *i.e.*, row-to-row and plant-to-plant spacings are important variables which

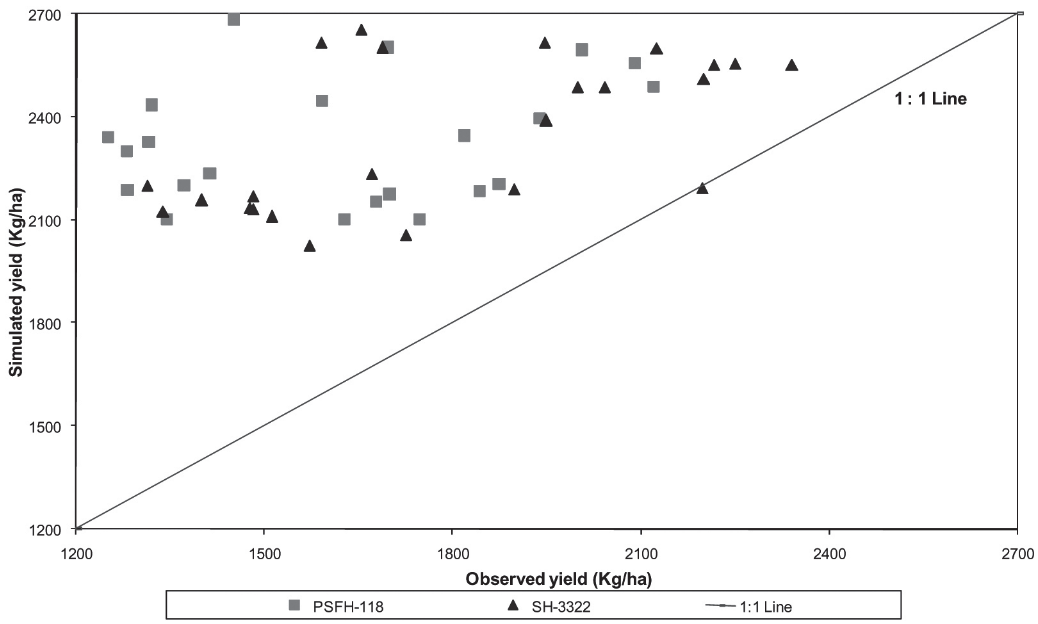

Fig. 6. Comparison between observed and simulated grain yields in sunflower cultivars under different environments (2003-04, 2004-05 and 2005-06)

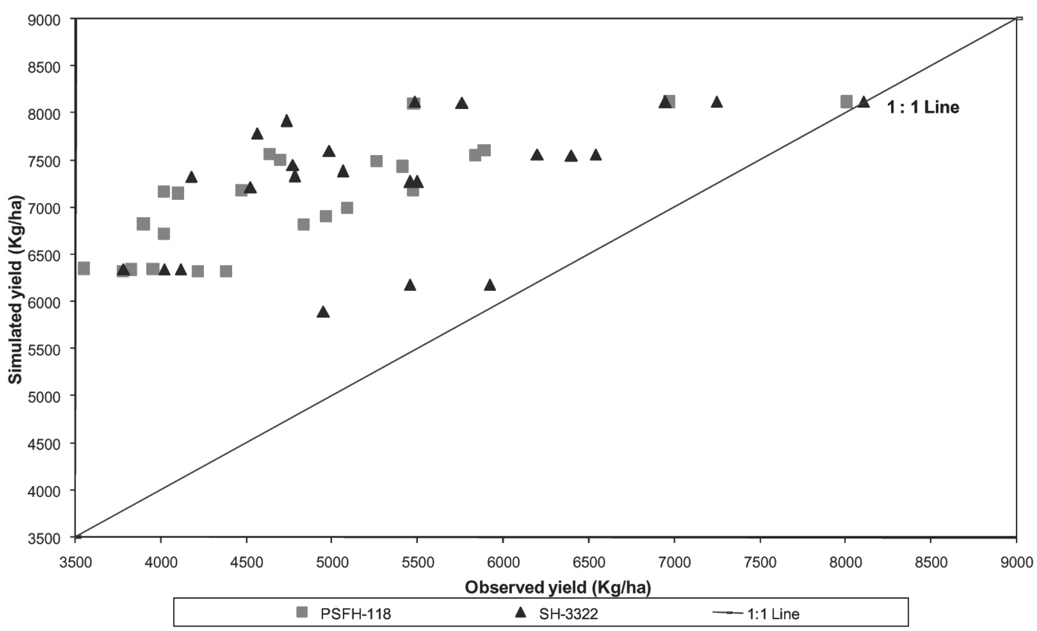

Fig. 7. Comparison between observed and simulated biomass yield in sunflower cultivars under different environments (2003-04, 2004-05 and 2005-06)

influence the growth of crop. When the row spacing was increased from 45 to 60 cm and then to 75 cm, grain yields decreased in all the dates of sowing. The potential yield of sunflower crop could be attained with a row-to-row spacing of 45 cm and plant-to-plant spacing of 30 cm, *i.e.*, 7.40 plants / m^2 were the most appropriate plant population stand (Table 3) as compared to the recommended row and plant spacing of 60 and 30 cm recommended through the package of practices by the agricultural university for sunflower (Anonymous, 2009).

Table 2. Effect of date of sowing on simulated yield of sunflower cv. PSFH-118 using OILCROP-SUN model

S.No.	Date of sowing	Estimated grain yield (kg ha^{-1})
1.	December 1	1525
2.	December 10	1556
3.	December 20	1817
4.	January 1	1334
5.	January 10	1311
6.	January 20	1620
7.	February 1	1604
8.	February 10	1936
9.	February 20	1885
10.	March 1	2183
11.	March 10	1810
12.	March 20	1573

Sunflower is a winter season crop and at the time of sowing, the soil temperature is low. The influence of variable seeding depth was also simulated for 10th January sown crop. The simulation results revealed that the optimum seeding depth of 2.5 cm can lead to the potential yield of 1979 kg ha^{-1}. The agronomic management options for the potential yield of sunflower crop in the simulation study were found to be in concurrence with those tested in the field conditions and included in the package of practices for crops.

Conclusions

Crop models can play important role in developing the decision support system for field crops by evaluating the available crop management options before the crop is actually sown. Our results indicate that the optimum time for sowing is 3rd week of December. The potential yield of the crop could be attained with a row spacing of 45 cm and plant spacing of 30 cm with 2.5 cm of seeding depth. Otherwise, the optimum management practices for the potential yield of the crop are in concurrence with recommended package of practices. The OILCROP-SUN model can be effectively used as a grower's tool for sunflower in Punjab.

Table 3. Effect of cultural management practices on simulated yield of sunflower cv. PSFH-118 using OILCROP-SUN model

S. No.	Date of sowing	Row-to-row spacing (cm)	Estimated grain yield (kg ha^{-1})
1.	December 1	45	1888
		60	1525
		75	1349
2.	December 10	45	1895
		60	1556
		75	1316
3.	December 20	45	2135
		60	1817
		75	1598
4.	January 1	45	1565
		60	1334
		75	1166
5.	January 10	45	1627
		60	1311
		75	1177
6.	January 20	45	1895
		60	1620
		75	1665
7.	February 1	45	1715
		60	1604
		75	1550
8.	February 10	45	2101
		60	1936
		75	1789
9.	February 20	45	2204
		60	1885
		75	1845
10.	March 1	45	2462
		60	2183
		75	1939
11.	March 10	45	2013
		60	1810
		75	1857
12.	March 20	45	1884
		60	1573
		75	1692

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